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MEMORANDUM FOR Howard Hogan
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Subject: Accuracy and Coverage Evaluation Survey: Correlation Bias (Prototype)

The attached document is a prototype of the report that we will prepare, per your request, following completion of applicable Accuracy and Coverage Evaluation Survey (A.C.E.) operations. The completed report is intended to aid the Executive Steering Committee on A.C.E. Policy (ESCAP) in its recommendation regarding the release of the statistically corrected data or the data without statistical correction as the P.L. 94-171 data. This report, together with other reports, will assess the operations and results of both the initial Census and the A.C.E. Both sets of assessments will be available to the ESCAP to aid the Committee in reaching its recommendation regarding the use of the statistically corrected data.

The attached prototype contains both empty table shells and a description of textual analysis that will assess specific aspects of the applicable operations. This report focuses on assessment of correlation bias in the A.C.E. estimates. The analysis is limited to comparison of estimates from demographic analysis with those from the census and A.C.E., and to use of demographic analysis sex ratios to develop estimates of correlation bias in the A.C.E. estimates under certain assumptions.

It is important to note that the conduct of the operations may lead us to modify the attached format by including additional information. It is also likely that descriptions and definitions will be enhanced or the data items could undergo revision. Conversely, we may conclude, for a variety of reasons, that some of the information set forth in the attached prototype may not be available. The attached document sets forth our conclusions prior to completion of the A.C.E. about what information would properly inform the ESCAP on this subject, but is subject to modification.

Accuracy and Coverage Evaluation 2000: Correlation Bias

prepared by William Bell

Introduction

Dual system estimates (DSEs) are said to contain bias if they systematically underestimate or overestimate the true population. Biases in the sample estimates of the components of the DSE formula can lead to biases in the DSEs, as discussed in Mulry (1991) and Mulry and Spencer (1991,1993). Even in the absence of any of these biases, DSEs can still be subject to another form of bias called *correlation bias*, resulting from failure of a general independence assumption that underlies the DSEs. This independence assumption can fail due either to *causal dependence* between the act of inclusion in the Census and the act of inclusion in the A.C.E., or due to *heterogeneity* across persons in the probabilities of being included in the Census and in the A.C.E. DSEs are constructed within post-strata to reduce heterogeneity in the inclusion probabilities, so that heterogeneity leading to correlation bias exists only if the inclusion probabilities vary across persons *within* a post-stratum. For further general discussion of correlation bias, see Griffin (2000).

When heterogeneity exists it is generally suspected to be of the form where persons (within a post-stratum) more likely to be included in the Census are also more likely to be included in the coverage survey (A.C.E.). Correlation bias resulting from this form of heterogeneity is negative, reflecting systematic underestimation of true population by the DSEs. The direction of the effect of causal dependence, if it exists, is less certain. It could be that persons included in the Census are made more aware of the Census process, and hence are more likely to be included in the A.C.E. than those missed by the Census. This type of dependence would lead to underestimation by the DSEs. Or it could be that persons included in the Census feel they have already responded to the Census Bureau, and so are more resistant to being included in the A.C.E. than those missed by the Census. This type of dependence would lead to overestimation by the DSEs. It is hard to say which of these two types of causal dependence might be more likely, thus, it is difficult to say whether correlation bias due to causal dependence would tend to lead to underestimation or overestimation by the DSEs.

One point worth noting is the implication of having both negative correlation bias (DSE underestimation) and net Census undercoverage as estimated by DSE. As noted in Bell (1993) and Bell et al. (1996), evidence of correlation bias in DSEs from the 1990 PES suggested negative correlation bias for the most undercounted groups, in particular, for adult black males. The implication of this is that the DSE is an underestimate of the true population, but the Census count is an even further underestimate. In short, the DSE contains (negative) correlation bias, while the Census count contains *both* undercount relative to the DSEs, and additional undercount corresponding to the (negative) correlation bias of the DSEs.

Two approaches have been used to investigate possible correlation bias in DSEs from a given post-stratification:

1. compare to results from demographic analysis,

2. compare to results from alternative post-stratification DSEs or more general models (e.g., logistic regression).

Both these approaches have strengths and limitations. Two other approaches that have been used that provide some evidence about possible correlation bias in DSEs are triple system estimation (Zaslavsky and Wolfgang 1993) and ethnographic observation. However, both these approaches have been used only in limited test sites, and so do not provide a basis for assessing correlation bias in estimates from the 2000 A.C.E.

Demographic analysis (DA), discussed by Robinson et al. (1993), has the advantage that its estimates are constructed from administrative data sources some of which (birth and death registration data) are generally believed to be quite accurate. Comparison of DSE results against DA estimates provides an aggregate check for correlation bias whether due to causal dependence or heterogeneity (with some qualifications regarding allowance for other biases, as discussed below). However, DA estimates are adversely affected by errors in the administrative data, such as uncertainty about the level of emigration from the U.S., and uncertainty about the level of undocumented immigration. For this reason, DA population estimates (DA totals) are thought to be less accurate than DA *sex ratios* (number of males over number of females). This reflects an assumption that errors in migration estimates are not grossly different for males than for females.

In addition to errors in its administrative data sources, the primary limitation on DA results is a lack of detail. Difficulties in using administrative data to construct estimates of subnational migration mean that subnational DA estimates, while providing useful indicators, are of significantly lesser accuracy than DA national estimates. Also, limited racial detail in the administrative data sources, along with differences in racial classification from the Census, limits separate DA estimates by race to simply Black and Nonblack. This limitation is likely to be more pronounced in 2000 than in 1990 with the allowance of multiple race responses to the 2000 Census, though any such effects are likely to be more important for making comparisons to DA totals than to DA sex ratios. Because of these limitations of DA, to investigate possible correlation bias in the 2000 ACE DSEs we shall only use DA data at the national level broken down by age (four A.C.E. age groups), race (Black and Nonblack groups), and sex. We shall use DA totals to provide rather crude checks on possible bias separately for males and females, and also for all children 0-17. If the female A.C.E. and DA totals are not too different, providing no evidence of significant correlation bias for females, as was the case in 1990 (Bell 1993), we will then use DA sex ratios to explore in more detail possible correlation bias for males.

The approach of comparing DSEs from a given post-stratification against DSEs from alternative post-stratifications or more general models was used in the research leading to the development of the A.C.E. post-stratification (Griffin 1999, Schindler 2000). One objective in this work was to use comparisons of post-stratified DSEs to estimates from a logistic regression "target" model to develop bias estimates for the DSEs. We found this approach to estimating bias was not very successful, however, probably due to failure of the underlying assumption that the target model produced estimates that were unbiased, or at least substantially less biased than the DSEs considered. More explicitly, the difference between two DSEs will reflect both the difference in their biases and some amount of random error, and unless the bias difference is substantial relative to the amount (standard deviation) of the random error, the resulting estimates of the bias difference will be poor. This was the case in the post-stratification research, where comparisons of DSEs from reasonable post-stratifications against estimates from the target model often resulted in negative estimates of squared bias (Schindler 2000). ("Reasonable post-stratifications" include those alternatives that appeared to reasonably balance potential bias reduction that might be achieved by increasing the detail of the post-stratification against the corresponding variance increase that would also result.) Thus, while logistic regression models provide an attractive way to investigate possible heterogeneity unaccounted for by the post-stratification, it is difficult to translate these results into correlation bias estimates, per se. This approach to investigating heterogeneity and its consequences will be pursued in further research beyond the 2000 Census, when there is more time to carefully develop and assess the results, but we will not use this approach here for estimating correlation bias in the 2000 A.C.E. estimates.

Wachter and Freedman (1999) criticized Census Bureau efforts to estimate correlation bias in the 1990 PES DSEs (Bell 1991, Mulry and Spencer 1993) for failing to allow for other estimated biases when estimating correlation bias. In principle, this criticism is valid. However, Spencer (2000) has noted that if the other biases are not very different between males and females, then, when using DA sex ratios, the effects of these other biases on estimates of correlation bias for the male DSEs will be small. Evaluations to estimate other biases in the A.C.E. DSEs will be carried out as part of the total error model analysis, but those results will not be available until late 2001. (Also, at this time, it has not yet been determined whether these evaluations will estimate the other biases separately by sex. Sample size limitations on the evaluations may preclude direct estimates with this level of detail. However, it is possible that models may be fit to the evaluation data to produce separate bias estimates by sex.) Given the time constraints, we will proceed with the assumption that the other biases are not very differential by sex, so that DA sex ratios can be directly used to assess correlation bias in the DSEs for males (assuming no correlation bias for females).

Assessments of Correlation Bias in the DSEs from the 2000 A.C.E.

Using DSEs from the 2000 A.C.E. and DA results for 2000, the following comparisons will be made. These and related results will be entered into the table shells given below.

1. Compare DA and DSE totals at the national level by age-sex-race (Black and Nonblack) as a crude check on bias. This will include checking for bias for adult females, since being able to assume no correlation bias for adult females is key to being able to use DA

sex ratios to assess correlation bias for adult males. (In comparing totals, the Wachter and Freedman (1999) criticism is relevant, so that these comparisons might be better regarded as assessing the total bias in the DSEs. This interpretation ignores, however, random error in the DSEs and errors in the DA estimates. Hence, this comparison can be thought of as a "crude check" on total bias.)

2. Assuming no evidence of significant bias for adult females (as was the case in 1990), sex ratios from A.C.E. and DA will be compared at the national level for age-race (Black and Nonblack) groups to provide a more refined check than in 1. of correlation bias for adult males. A related comparison can be made by applying the DA sex ratios to the A.C.E. results for adult females (national level, by age-race groups) to provide comparison totals for adult males. These comparison totals serve as control totals in the next step.

3. Taking the control totals for adult males from 2., alternative models will be used to combine results from DA and A.C.E. (Bell 1993) to provide correlation bias estimates for adult male post-strata. These models essentially allocate to these post-strata the correlation bias for adult males estimated at the national level within age-race groups. Alternative combining models are presented in Bell (1993) and Bell et al. (1996). Statistical refinements to this approach have been developed by Elliott and Little (1999), but their approach would be difficult or impossible to implement in the time allowed, and these refinements are likely to be less important than alternative choices of the combining model. The approach of Elliott and Little (1999) is planned for use later in the total error evaluations.

Note: The allowance of multiple race responses in the 2000 Census complicates comparisons between DA and the Census, and hence between DA and A.C.E. This is discussed by Robinson (2000), who explains how alternative Census tabulations corresponding to alternative definitions of the Black and Nonblack groups will be used in comparisons. If these alternatives lead to materially different results for the comparisons reported here, then alternative tables corresponding to these alternative results will be reported. The effects of the alternative definitions should be much larger for the Black than for the Nonblack group. Also, as alluded to above and in Robinson (2000), it is possible that the effects of the alternative definitions on the sex ratios for both Blacks and Nonblacks will be small.

Note: Some results from 1990 may be added to the following tables to provide comparisons against the 2000 results.

Table 1. Population Totals (in millions) from the Census, Demographic Analysis (DA), and A.C.E.

(removing residual population[1] = group quarters population plus remote Alaska population)

Nonblacks

Children:

Age-Sex	residual population	Census	Census - residual pop	DA	DA - residual pop	A.C.E. w/o residual pop
0-17 male						–
0-17 female						–
0-17 total						

Adult Females:

18-29						
30-49						
50+						

Adult Males:

18-29						
30-49						
50+						

[1]Since the A.C.E. estimation universe does not include the group quarters and remote Alaska populations, we subtract the Census count of these populations from the DA and Census population totals. The resulting numbers can be compared to the direct A.C.E. estimates obtained by aggregating DSEs across post-strata within the age-sex-race (Nonblack versus Black) groups. This removal of the residual population from DA is necessary to use it to assess correlation bias in the DSEs. The population totals in this table thus differ by the residual population from the usual population totals (which, for A.C.E., are obtained by taking the above results and adding to them the Census count of the residual population.)

Table 1. (continued) Population Totals (in millions) from the Census, Demographic Analysis (DA), and A.C.E.

(removing residual population[1] = group quarters population plus remote Alaska population)

Blacks

Children:

Age-Sex	residual population	Census	Census - residual pop	DA	DA - residual pop	A.C.E. w/o residual pop
0-17 male						–
0-17 female						–
0-17 total						

Adult Females:

18-29						
30-49						
50+						

Adult Males:

18-29						
30-49						
50+						

Table 2. A.C.E. and DA Estimates of Net Census Undercount[2], and DA Estimates of Net A.C.E. Undercoverage[3]

Children:	Nonblacks			Blacks		
Age-Sex	Net Census Undercount relative to A.C.E. (%)	Net Census Undercount relative to DA (%)	Net A.C.E. Undercover-age relative to DA (%)	Net Census Undercount relative to A.C.E. (%)	Net Census Undercount relative to DA (%)	Net A.C.E. Undercover-age relative to DA (%)
0-17 male	–		–	–		–
0-17 female	–		–	–		–
0-17 total						
Adult Females:						
18-29						
30-49						
50+						
Adult Males:						
18-29						
30-49						
50+						

[2]The net Census undercount percent relative to A.C.E. is 100(ACE - Census) / ACE. The net Census undercount relative to DA is 100(DA - Census) / DA. The population totals used in the computations here are defined to include the group quarters and remote Alaska populations, for comparability to undercount percents cited elsewhere.
[3]The net A.C.E. undercoverage percent relative to DA is 100(DA - ACE) / DA. Again, the population totals used in these computations are defined to include the group quarters and remote Alaska populations.

Table 3. Adult Sex Ratios[4] from the Census, A.C.E., and Demographic Analysis (DA)

	Nonblacks			Blacks		
Age	**Census**	**ACE**	**DA**	**Census**	**ACE**	**DA**
18-29						
30-49						
50+						

[4]The sex ratios are obtained by dividing the male population totals from Table 1 by the corresponding female population totals. Thus, the group quarters and remote Alaska populations are not included in the computation of these sex ratios.

Table 4. Adult Male Control Totals[5] Using A.C.E. Female DSEs and DA Sex Ratios
(population totals are in millions)

	Nonblacks				Blacks			
Age	**A.C.E. Females**	**DA Sex Ratio**	**DA Male Controls**	**A.C.E. Males**	**A.C.E. Females**	**DA Sex Ratio**	**DA Male Controls**	**A.C.E. Males**
18-29								
30-49								
50+								

[5]The adult male control totals are obtained by multiplying the A.C.E. totals for adult females (taken from Table 1) by the corresponding DA sex ratios (taken from Table 3).

Table 5. Assumptions Underlying Alternative Models[6] for Combining A.C.E. and DA

Model	Assumption
1. Two-group (2 group)	Correlation bias in post-stratum proportional to *E*(DSE).
2. Fixed odds ratio (FOR)	Correlation bias in post-stratum proportional to *E*[estimate assuming independence of number missed by both Census and ACE].
3. Fixed relative risk (FRR)	Correlation bias in post-stratum proportional to *E*[estimate assuming independence of Census undercoverage].
4. Fixed ratio of male to female p_{22} (MF22)	Ratio of male to female probabilities for (2,2) cell (not in Census, not in ACE) constant over post-strata (within age-race groups).
5. Generalized behavioral response estimator (BRE)	Pr[in ACE | not in Census] / Pr[in Census] constant over post-strata (within age-race groups).

[6]The combining models derive from alternative assumptions that some quantity (parameter) is constant across all (male) post-strata within an age-race (Nonblack versus Black) group. Model 1 is described in Bell (1999, Attachment A). Models 2-5 are taken from Bell (1993) and are also discussed by Elliott and Little (1999). Consult these references for mathematical details.

Table 6. Parameter Estimates for Alternative Models[7] Combining A.C.E. and DA Results

	Age	2-group (η^{-1})	FOR (θ)	FRR (γ)	MF22 (ρ^{-1})	BRE (λ)
Nonblacks	18-29					
	30-49					
	50+					
Blacks	18-29					
	30-49					
	50+					

[7]The alternative models are those listed in Table 5. Values of the parameters exceeding 1 are indicative of potential (negative) correlation bias resulting in underestimation by DSEs.

Table 7. Alternative Correlation Bias Estimates[8] for Adult Male Post-strata (expressed as net undercoverage percents)

PSID[9]	2-group	FOR	FRR	MF22	BRE
1					
2					
3					
4					
5					
6					
etc.					

[8]The alternative models used are those listed in Table 5. See Bell (1999, Attachment A) and Bell (1993) for details on how the alternative post-stratum DSEs are constructed. For a given model, the correlation bias estimate for a post-stratum is expressed as a net undercoverage percent for the conventional DSE by taking 100 times the alternative DSE less the conventional DSE divided by the alternative DSE. The assumption underlying the 2-group model implies that this estimated undercoverage percent is constant over post-strata within an age-race group.
[9]PSID is the post-stratum identification number.

Note: Because of the large number of post-strata, the above table may be replaced by a set of graphs.

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